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Geodetic Support for the Use of Natural Resources of Chernivtsi Region Using GIS

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Abstract

Maps and plans are necessary to obtain accurate spatial information about the location of any geo-objects. High-quality and accurate creation of cartographic materials will improve the assessment of natural resources, cadastral work, etc. to solve the problem, cadastral maps and plans of a given scale are necessary. Their creation without violating regulatory documents requires certain State Geodetic Network (SGN) points. The purpose of the study is to analyse the spatial location of SGN points on the territory of the Chernivtsi region in Ukraine and to assess geodetic support for the use of natural resources using geographic information systems (GIS). We used QGIS version 3.28, to create maps and models based on the thematic layers, and evaluated the existing geodetic support in the section of the newly created administrative and territorial units of the region. An assessment of the spatial placement of SGN points for the territory of the Chernivtsi region by the administrative-territorial division was carried out. We identified 198 geodetic points of different classes. The boundaries of Chernivtsi district had the largest number of geodetic points (109 units, which is 55% of the total region). This was followed by Dnistrovsky District (54 points - 27% of the region), and Vyzhnytsky District (35 objects - 18% of the region).

Keywords

Geodetic support; GIS; Topographic and geodetic works; State geodetic network; Natural resources

Introduction

The problem of topographic support in Ukraine is the ageing of the content on cartographic materials. In addition, the main materials

for conducting a large complex of various land management, urban planning, geological exploration and management activities are plans and maps of the area created thanks to topographical and geodetic works. Topographic maps of scales 1:500, 1:1 000, and 1:2 000 are needed to ensure various types of activities. According to the technology of obtaining plans, it is necessary to ensure high accuracy in determining the coordinates of reference points from 0.1 to 0.4 m with sparse (5-10 km) State Geodetic Network (SGN) (Instructions for topographic surveying at scales, 1991).

The basis of topographic surveys of any scale is the State Geodetic Network, which forms a set of points that are evenly located within the country and fixed on the ground by special centres that ensure their preservation in plan and elevation for a long time. In addition, it serves as the basis for the establishment of a unified geodetic system of coordinates and heights on the territory of Ukraine, cartographic and geodetic support of its territories and ensures the conduct of other types of activities. Among the branches of natural and economic use, geodetic work is an integral part of settlement territories, in particular, their development. Therefore, the study of geodetic support at all stages of construction works is relevant, both in the conditions of today and in past years. Therefore, the study of the existing features of topographical and geodetic support, as an accurate and reliable basis for any other pre-qualification works, is quite relevant and promising.

SGN is created to solve such basic tasks in the interests of economic activity, science and defense of the country as: (1) establishment of a unified geodetic system of coordinates and heights on the territory of the country (Stanková and Černota, 2010), (2) geodetic support for mapping the territory of the country, sea areas and inland water bodies (Jadviscok, 2023), (3) geodetic support for the study of natural resources and maintenance of state cadastres (Berk and Ferlan, 2016), (4) provision of initial geodetic data for means of land, sea and aerospace navigation, aerospace monitoring of the environment (Darchuk *et al.*, 2021; Palamariu and Puscas, 2014; Suyunov *et al.*, 2023), (5) the study of the shape and gravitational field of the Earth and their changes over time, (6) the study of geodynamic phenomena and modern vertical movements of the Earth's surface (Klatt, 2016), (7) the study of the deformation zones of the earth's surface, (8) the study of the movements of the poles and the unevenness of the Earth's rotation, and (9) metrological provision of high-precision technical means of determining the location and orientation (Hu, 2024; Sánchez *et al.*, 2024).

For high-quality topographical and geodetic works, it is important to provide the territory with SGN points. For the reliable functioning of the SGN, it is necessary to constantly inspect and update its points by the regulatory document (Law of Ukraine "On topographical, geodetic and cartographic activities", 1998).[1] This is necessary for their preservation in the area and maintenance in proper condition. The need to carry out significant volumes of topographic and geodetic works to update topographic maps slows down their updating. This prompts selective updating of only the most important elements of the geographic base of the map. The second way out of this situation is to use more productive methods of obtaining alternative geospatial data (orthophoto maps,

[1] Law of Ukraine "On topographical, geodetic and cartographic activities" (1998). 353-XIV. Available at: http://zakon4.rada.gov.ua/laws/show/353-14.

orthophoto plans, etc.). Newer methods are also significantly cheaper. Topogeodetic support is also an integral component of the geoinformation support of the armed forces of Ukraine. Also, SGN can play an important role in the event of military operations, if the enemy disables the GNSS system in a certain area. The latter happened in Ukraine in recent years due to the war in the country. In this connection, there is a need to obtain information on the provision of territories with SGN points.

Analysis of the specified geodetic problem in Ukraine by various authors and researchers shows that the state of the SGN and discrete geodetic networks allow the creation of maps and plans, without violating regulatory documents, only for small scales. In previous years, various authors, following Bilokrynytskyi, Darchuk and Melnyk (2023), analyzed the creation of cartographic materials of various scales. These studies conclude that the creation of map materials is possible only for certain areas of the territory of the Chernivtsi region of Ukraine. Taking into account the changes in the administrative system of the country by the decentralization reform, it is necessary to carry out analysis, and calculations, to determine the features of spatial placement and distribution of both individual SGN points and geodetic support in general. In light of the above research gaps, this study aims to analyse the spatial location of SGN points and the assessment of geodetic support for the use of natural resources in the territory of the Chernivtsi region of Ukraine using GIS.

The purpose of the study is to determine the location of SGN points within administrative units. Taking into account regulatory requirements - their quantitative indicators by area of the territory will allow for assessing the geodetic support of the Chernivtsi region. The latter will allow qualitative and accurate planning of the creation of map materials for various purposes.

Review of Literature

The issues of geodetic nature in the territory of Ukraine were considered in the works of such scientists as Lepetyuk *et al.* (2006), Sossa and Musienko (2018), Trevogo (2018), Trevogo, Ilkiv and Galyarnyk (2022), Zayets (2010), and Karpinskyi and Hevel (2022). These studies mainly relate to the analysis of the problem under study for the territory of the entire country. In our opinion, insufficient attention is paid to the research of these problems at the regional level. Among the publications, there are studies by Bilokrynytskyi, Darchuk and Melnyk (2023), and Darchuk *et al.* (2021) are devoted to the problems of geodetic support at the regional level. This allows for a deeper understanding of all existing problems and to outline possible ways to solve them.

The rapid development of satellite geodesy in recent years has become the impetus for the integration and change of national geodetic bases in the global continental system (Palamariu and Puscas, 2014; Stankova, 2010). Separate studies have focused on the development of a GPS-based geodetic network setup strategy for the permanent determination of national geodetic control point coordinate sets (Jung and Lee, 2011). The research procedure was analyzed, and how triangulation points were transformed into results based on the world geodetic system was analyzed (Lee and Jung, 2011). A study of the stationary modes of satellite networks and triangulation points was conducted. The results of the studies conducted using satellite methods in the Samarkand

region showed that there are differences between the distances from the reference station and the errors in determining coordinates and distances. To increase the accuracy of geodetic support decisions made using satellite means, it is worth building networks of reference stations, which is a new technology (Suyunov *et al.*, 2023).

Quite valuable for global cooperation in geodesy, survey science and land surface mapping: On 29 March 2023, the UN Global Geodetic Center of Excellence (UN-GGCE) was officially opened at the UN campus in Bonn. The government-led coordination of the development of a permanent global geodetic infrastructure is one of the most important tasks of the UN GGCE. Data and analysis centres and observation stations around the world belong to the infrastructure. This, in turn, is of paramount importance for observations of the Earth, as well as for navigation. In addition, it is important for various spheres of life, in assessing climate change, and land use research.

The creation of GGOS, the Global Geodetic Observation System of the International Association of Geodesy (IAG), provided for the emergence of an integrating framework for all components of the IAG. GGOS constantly monitors and changes its most important priorities in connection with new needs in geodesy. As a result, a new GGOS Strategic Plan for 2024-2034: Geodesy for Science and Society (Sánchez *et al.*, 2024). Works on the reliability of geodetic measurements, probabilistic determination of reliability, tolerance systems and error detection methods were analyzed (Abid, Husein and Hamed, 2020). Today, the problem of reliability is becoming one of the important components in the organization of management. Ensuring the reliable operation of all system elements is of primary importance (Gladilin *et al.*, 2023).

It is important to consider the methodological problems of legal determination of the plot boundary and plot area about the theoretically precisely defined boundary of the geodetic plot and the territory of the geodetic plot on the reference ellipsoid (Berk and Ferlan, 2016). Separate publications reveal the importance of the existence and functioning of the national infrastructure of spatial data in Ukraine, which would allow a comprehensive and more effective approach to the conducted research. The concept for the development of topographic mapping was created in Ukraine using the existing standards and specifications. When developing the National Spatial Data Infrastructure, this corresponds to the geoinformation approach to topographic mapping.

Works on the evaluation of the effectiveness of the use of geodetic data in the processes of planning and monitoring agro landscapes are considered. Such studies are focused on determining the role of these data in improving land use systems and developing natural resource conservation strategies. Adaptive landscape land management, based on GIS, contributes to the preservation of the ecological skeleton of natural complexes and controls the anthropogenic impact on the environment. The specifics and complexity of solving a complex of water management tasks in geodetic practice have been clarified. This contribution refers to the geodetic activity, which is related to the measurement of watercourses and their immediate area (Jadviscok and Gottvaldova, 2023).

Methodology

The possibilities of using geospatial analysis methods to provide SGN for mapping of

various scales were investigated using the example of the Chernivtsi region (area - 8097 km^2, located at latitude 48°12′09.36″ north and longitude 26°13′14.88″ east). Geospatial analysis methods were used for the research, in particular, zoning of the territory using buffer polygons.

1. Spatial Mapping:

GIS analysis was done using the software QGIS version 3.28.15. Thematic layers were vectorized, and a database of researched geo objects was created. Based on them, map schemes were created, which allowed the evaluation of the existing geodetic support. Maps and plans were then created at various scales in terms of administrative and territorial units of the territory. The following methods were used during the research: cartographic (thematic map schemes were created using the QGIS version 3.28.15), statistical and mathematical (using Microsoft Excel and QGIS version 3.28.15 statistical analysis, calculations were made regarding the number of points by administrative entity, the size of the buffer around the SGN points, and the area of territories with non-compliance with geodetic support), descriptive (allowed us to identify and analyze areas of territories characterized by non-compliance with the geodetic support requirements for the placement of SGN points to create maps of the appropriate scale). We considered the possibility of exporting vector layers of borders of administrative entities according to the latest administrative-territorial division of Ukraine from the official open-source website of the Ministry of Community and Territorial Development of Ukraine (https://mtu.gov.ua/). The downloaded file with the appropriate GEOJSON extension was imported into QGIS. To confirm the exact placement of the exported borders to the GIS product, the raster layers of OpenStreetMap, and Google Satellite Hybrid were enabled as a geobase, which allowed us to visually verify the coincidences.

2. Data Collection:

Data on the spatial and attributive characteristics of points of the state geodetic network were obtained from the official website of the state geodetic network of Ukraine (https://dgm.gki.com.ua/login). A geodatabase for points of the SGN was created using this data (coordinates of points, their height, name, update period). One of the attribute characteristics of geo objects was their coordinates, which made it possible to automatically open already vectorized point objects in QGIS.

According to the currently existing regulatory documents in Ukraine (Instructions for topographic surveying at scales, 1991)[2]: " The average density of geodetic points should be at least one point per 30 km^2 (for creating topographic maps and plans on a scale of 1:10000 – 1:25000). For the geodetic support of the topographic survey, the following norms of the density of geodetic points and benchmarks of the State Geodetic Network exist by the requirements of regulatory documents:

- on a scale of 1:25000 and 1:10000 - one point per 30 square kilometres and one benchmark per trapezoid on a scale of 1:10000;
- on a scale of 1:5000 - one point per 20-30 square kilometres and one

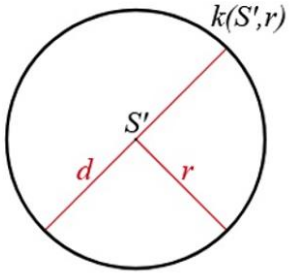
[2] Law of Ukraine "On topographical, geodetic and cartographic activities" (1998), 353-XIV. Available online at: http://zakon4.rada.gov.ua/laws/show/353-14.

benchmark per 10-15 square kilometres;
- on a scale of 1:2000 and more - one point per 5-15 square kilometres and one benchmark per 5-7 square kilometres."

For topographic and cadastral surveying on a scale of 1:2000 and more, points of geodetic thickening networks and shooting geodetic networks are determined in addition to the geodetic points of the State Geodetic Network. A further increase in the number (density) of geodetic points of the State Geodetic Network is created based on the results of the substantiation and calculations carried out based on the specific tasks of topographic-geodetic and cartographic activities in a certain territory.

3. Statistical Calculations:

Because of this, an assessment of the possibility of drawing up topographic maps and plans for the studied territory using the methodology of Bilokrynytskyi, Darchuk and Melnyk (2023) was carried out (Fig. 1). Geometric constructions are applied that simulate the coverage of the region with the corresponding area. For the present study, we used a circle with the same distance from its centre to the arc, corresponding to the radius value.



$$S = \pi r^2 = \frac{\pi d^2}{4}$$

$$P = 2 \cdot \pi r = \pi d$$

$$d = 2 \cdot r$$

$$\pi \doteq 3,14$$

Figure 1: Algorithm for determining the area of a circle (P - perimeter, S - area, r – radius, d – diameter, S´- centre) (Bilokrynytskyi, Darchuk and Melnyk, 2023)

Calculations showed that for updating the basic scale of the topographic map (scale 1:10000), 1 point covers 30 km^2, i.e., a territory measuring 5x5 km, or with the area of influence of the point in a radius of 3091 m, for the compilation of cartographic material with a scale of 1:5000, 1:2 000, 1:1 000 and 1:500, the radius of the figure will be 2523 m, 2 185 m, 1 784 m and 1 261 m, respectively (Table 1).

Table 1: Values of circle radii when drawing up a map (plan) of the appropriate scale (Instructions for topographic surveying at scales, 1991)[3]

Scale	Area S, km^2	Radius r, km	Diameter d, km
1:10 000-1:25 000	30	3,091	6,182
1:5 000	20	2,523	5,046
1:2 000	15	2,185	4,370
1:1 000	10	1,784	3,568
1:500	5	1,261	2,522

[3] Law of Ukraine "On topographical, geodetic and cartographic activities" (1998). 353-XIV. Available at: http://zakon4.rada.gov.ua/laws/show/353-14.

4. Visualization in QGIS:

To determine compliance with the requirements, buffers with the appropriate radius of action were created for vectorized point objects through the menu in QGIS "Vector" - "Geoprocessing tools" - "Buffer". The calculation of the area of the entire territory with indicators of inconsistency (areas not covered by buffers) was carried out. Due to the functionality of the main menu in QGIS, "Vector" - "Data processing" - "Difference" is selected. In the following settings, it is selected between which two vectorized layers to perform the selected difference. The choice was made between polygonal objects of district territories and created buffers. After that, we will have only vectorized individual objects corresponding to areas of discrepancy in the average density of SGN points. By leaving the boundaries of administrative districts for research and opening the table of attributes of the pre-created layer of areas of inconsistency, it was possible to create additional fields of attribute characteristics that would show the size of the area of areas of inconsistency within individual formations. Pre-painted actions through the selected "Vector"-"Data processing"-"Difference" were carried out for the polygonal layer of settlements and buffers of the corresponding radius. Due to the possibilities of layout of map schemes in QGIS, settings have been made with the visualization of research results in the form of maps.

Results

1. Data Collection and Analysis:

In 2020, the second stage of the decentralization process ended in Ukraine. By the resolution of the Verkhovna Rada of Ukraine "On the formation and liquidation of districts" dated 07.17.2020, 3 administrative districts were formed in the territory of Chernivtsi region: Chernivtsi Dnistrovskyi and Vyzhnytskyi. In addition, 52 units of territorial communities with a population of almost 902 thousand people are functionally operating. In the conducted research, an assessment of the spatial location of SGN points for the territory of the Chernivtsi region in terms of modern districts and territorial communities was made. It was established that the number of geodetic points totals 198 units of different classes, of which: 1st class – 13 units; 2nd class – 68 units; 3rd class – 117 units; digit geodetic network (4th class) – 96 units (Fig. 2). Within the boundaries of Chernivtsi district there is the largest number of SGN points with a total number of 109 units, which is 55% of their total number in the region. There are 54 points (27%) within the Dnistrovskyi district and 35 points (18%) within the Vyzhnytskyi district.

Spatial analysis of the placement of SGN points in the section of territorial communities shows that the most points are located in the territory of Chernivtsi - 41 units, half as many - 23 points are located in the territory of Sokyryansk urban territorial communities. Also, with an indicator of more than 10 points, Storozhinetsk City - 16 Kelmenetska - 16 and Berehometsk - 11 points stand out. One of the solved tasks was to conduct an analysis of the spatial arrangement of points of the SGN of different classes in the cross-section of administrative units: districts and communities. It was established that the largest number of 1st-class points are located in the territory of the Dnistrovskyi district - 7 units, Chernivtsi - 5, Vyzhnytskyi - 1.

The largest number of 1st-class SGN points in terms of basic units of the administrative-territorial system in the territory of Kelmenetska - 3 and Sokyryansk communities - 2 points (Shebutyntsy, Sokyryany). Most territorial communities are characterized by the absence of 1st-class SGN points. The largest number of 2nd class SGN points are concentrated in Chernivtsi district - 37 units, in second place is Vyzhnytskyi district - 17 units, and in Dnistrovskyi - 14 points. The largest concentration of them in the territory of the Berehomet community is 5 units. There are 4 points each within the Kelmenetska and Chagorsk communities, and 3 points of SGN of the corresponding class are available in the Selyatynsk and Ust-Putilsk TGs. For the rest of the territories of communities, the number is from 2 to 1 point. On the territory of Chernivtsi region, territorial communities with the absence of 2nd class SGN points were identified, among them: Khotynska, Novoselytska, Magalska, Velikokuchurivska, Suchevenska, Chudeyska, Mamaivska, Brusnytska, Banylivska, Nepolokovetska, Stavchanska, Kostryzhivska.

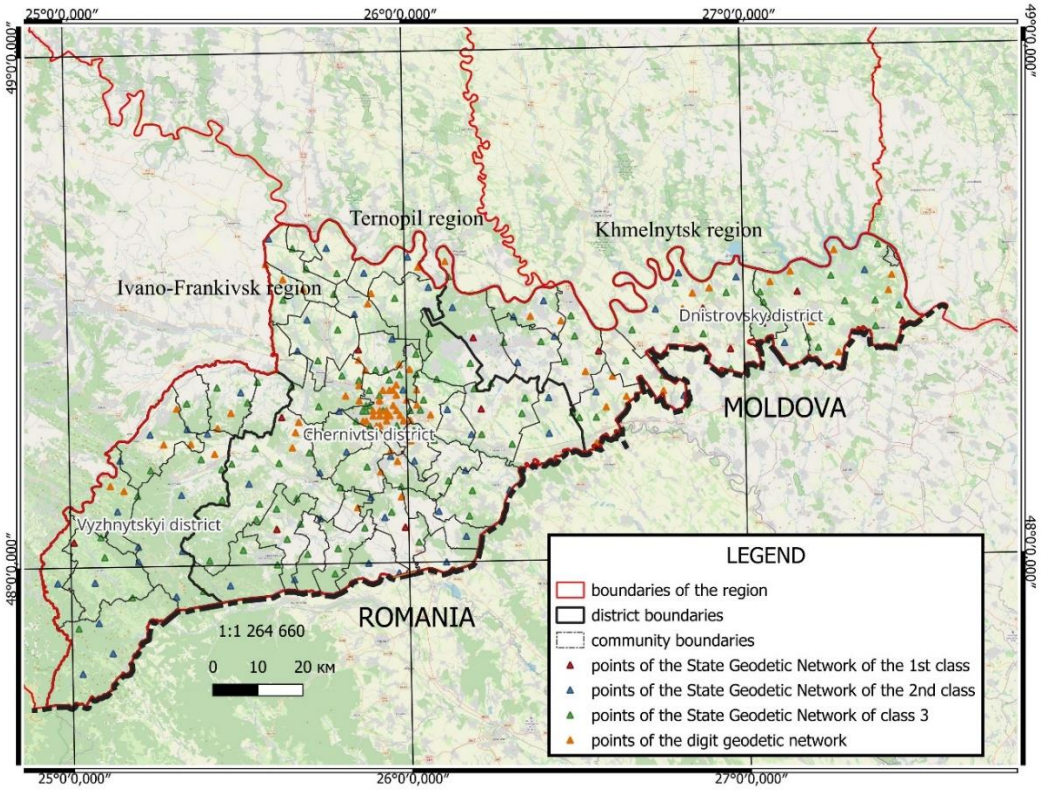


Figure 2: Spatial location of SGN points on the territory of Chernivtsi region (image created using QGIS)

Within the boundaries of Chernivtsi district, the largest number of 3rd class SGN points was also found in the amount of 67 points, in the territory of Dnistrovskyi District - 33, and Vyzhnytskyi - 17 objects. The highest concentration of SGN points of the 3rd class is observed in the territory of the Chernivtsi community - more than 15 units, Sokyryansk and Storozhynetsk communities are located from 9 to 12 points, and in the remaining territories of the communities their number is smaller. According to the results of the spatial analysis of the distribution of points of the digit geodetic network (4th class), it was found that most points are concentrated in the territory of Chernivtsi district - 52

units, within the boundaries of Dnistrovskyi - 26, and in the territory of Vyzhnytskyi - 18 objects. Research in the cross-section of territorial communities revealed the highest concentration of points in the Chernivtsi community, while Sokyryanska is far behind - at 7, and Kelmenetska, and Mamalygivska - at 3 points each. In the territories of most of the newly formed territorial communities, there are no SGN points of the discharge geodetic network.

2. Statistical Calculations:

In the course of the research, the area of the entire territory was calculated with the above-mentioned inconsistency indicators. There are 2,726.91 km^2 of territories of various shapes of areas of non-compliance with the average density of SGN points, which is 33.7% of the total area. The largest area of the indicated areas of non-conformity is characteristic of Chernivtsi district - 1281 km^2 (30%), Vyzhnytskyi 869 km^2 (43%) and Dnistrovskyi 576 km^2 (27%) of the territory of administrative districts. Significant areas of non-conformity territories are characteristic of Selyatynska village - 238.85 km^2 (65% of the total area of the administrative entity), Beregometska - 215.46 km^2 (44%), Kelmenetska settlement - 157.9 km^2 (29%) and Storozhynetsk urban communities - 157.5 km^2 (30%). The spatial distribution of the areas with the maximum indicators of inconsistency is observed with the distance of territorial communities from the regional centre in the western and eastern directions (Figure 3).

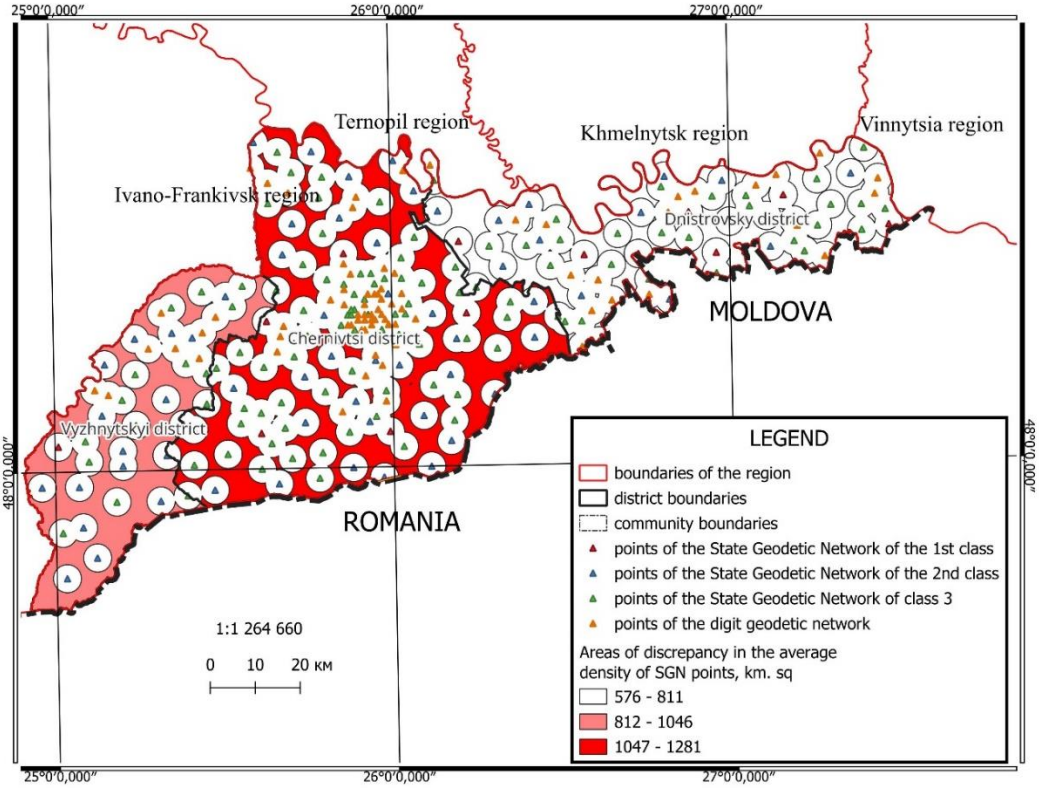


Figure 3: Vectorized objects, areas of discrepancy in the average density of SGN points in the section of administrative districts (image created using QGIS)

The values of the smallest inconsistencies in the average density of points of SGN are

typical for Chernivtsi city - 0 km^2 (0%), Chagorska - 6.9 km^2 (13.8%), Mamalygivska 7.9 km^2 (5.5%), Magalska - 7.19 km^2 (8.6%), Horishnyosherovetska - 14.2 km^2 (16.4%) of rural communities (Fig. 4). Spatial distribution of territories with minimum indicators shows their location close to the regional centre.

3. Research in QGIS:

If we analyze and consider the possibility of creating maps and plans of different scales, the area covered by the SGN points (buffer radius) will vary from 3.1 (at a scale of 1:10000-1:25000) to 1.26 (at a scale of 1:500). When the scale is increased, there is also an increase in the number of required designed SGN points. When assessing the possibility of drawing up topographic plans, it is important, mainly, to cover the territories belonging to built-up areas, that is, it concerns settlements. According to the cartographic materials shown in Fig. 2 and 3 location of SGN points with their radius of action is inherent in both built-up and non-built-up parts. Because of this, there is a need to determine the area covered by the buffers of the SGN points of the built-up areas.

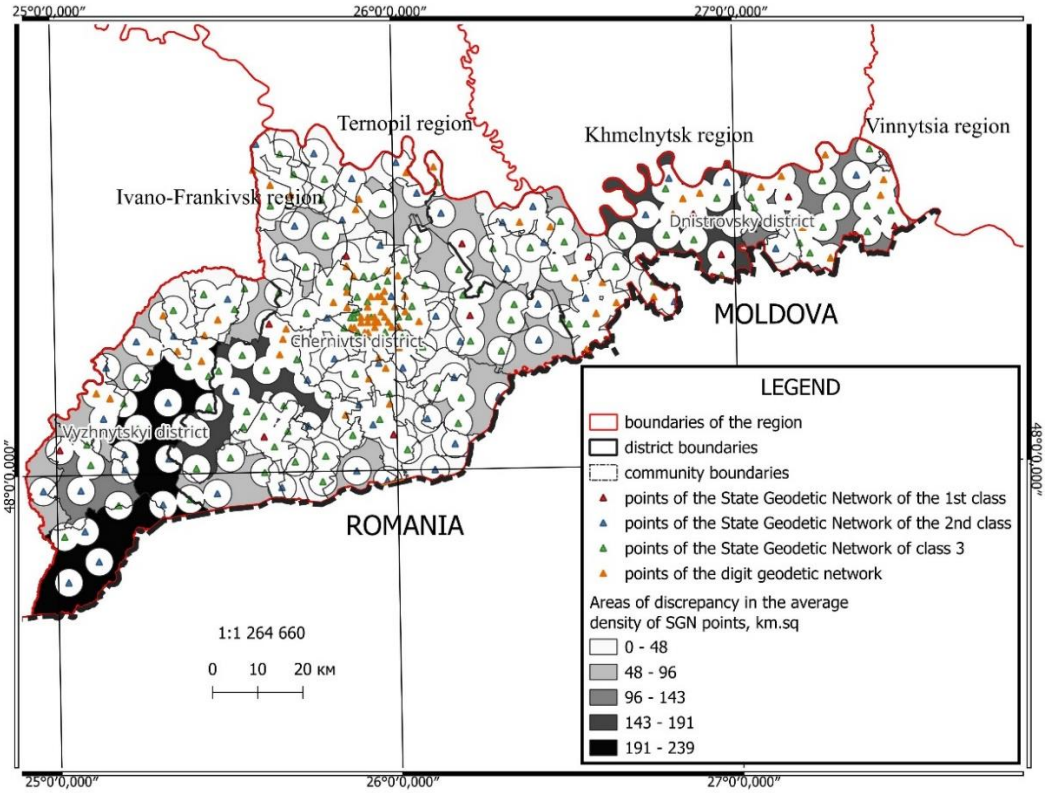


Figure 4: Vectorized objects, areas of inconsistency in the average density of SGN points in the section of territorial communities (image created using QGIS)

Vectorization of settlements in the form of polygonal thematic layers was carried out (Fig. 5). Taking into account that topographic plans should cover the territories of populated areas, an overlay analysis of vectorized objects and the topographic base was carried out (Fig. 6). A topographic map on a scale of 1:100 000 allows seeing the qualitative component of territory coverage. Yes, even if only built-up areas are taken

into account, there will not be enough SGN points for these objects as well. Moreover, a significant number of points are concentrated in open terrain, which makes it possible to compile only large-scale maps. If there is a need to update topographic plans on a scale of 1:2 000, 1 point (on average) must be located on 10 km^2, that is, it covers an area of 3.15 km x 3.15 km, which will further reduce the productivity of the existing SGN network. Therefore, the existing density of SGN points, in most cases, does not satisfy the existing requirements, even when drawing up and updating topographic plans of scales 1:5000 and 1:2000.

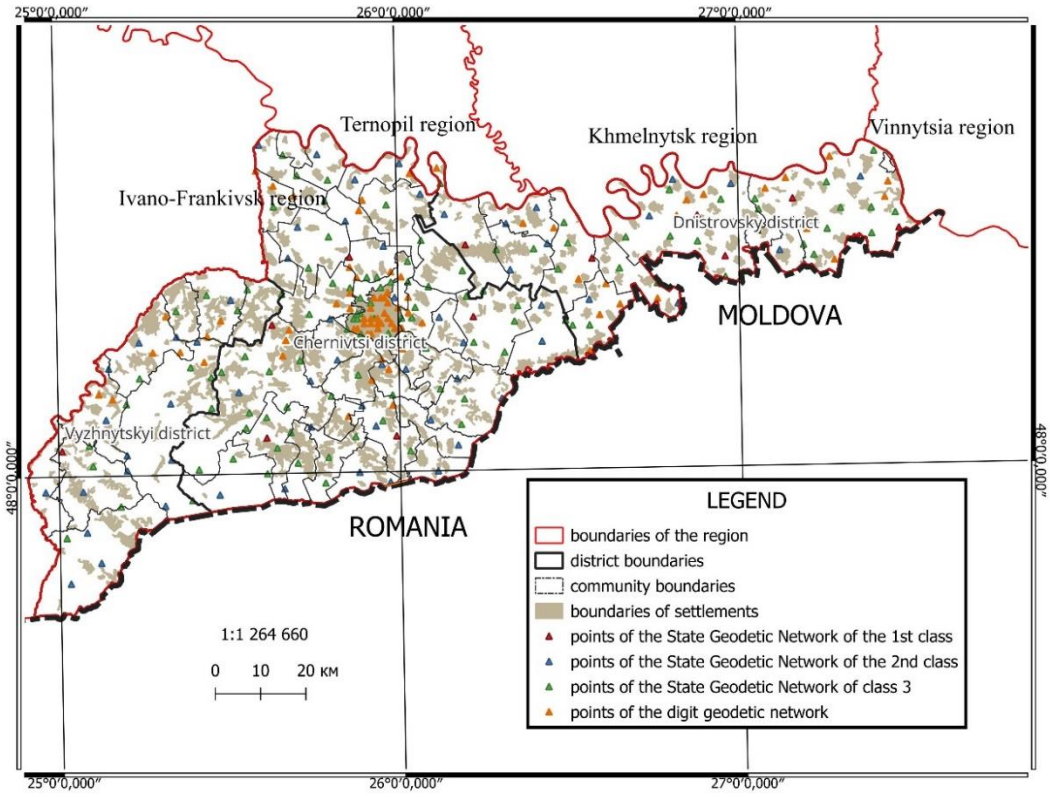


Figure 5: Vectorized boundaries of settlements in the territory of Chernivtsi region (image created using QGIS)

4. Analysis of the Obtained Data:

For topographic and cadastral surveying on a scale of 1:2000 and more, the points of discharge and survey geodetic networks are determined in addition to the SGN points. In addition, the problem of low density of points can be solved by using satellite geodetic methods to determine the points of shooting networks. That is, to carry out large-scale surveying, a single-digit geodetic network is needed, which was created only for urban settlements. Thus, the one-digit geodetic network of one of the settlements in the research area shows that in the 1970s and 1980s, 121 polygonometry points of the 1st and 2nd degrees were laid on the territory of the city (Fig. 7). At that time, they fully met the requirements of the current regulations on topographical surveying.

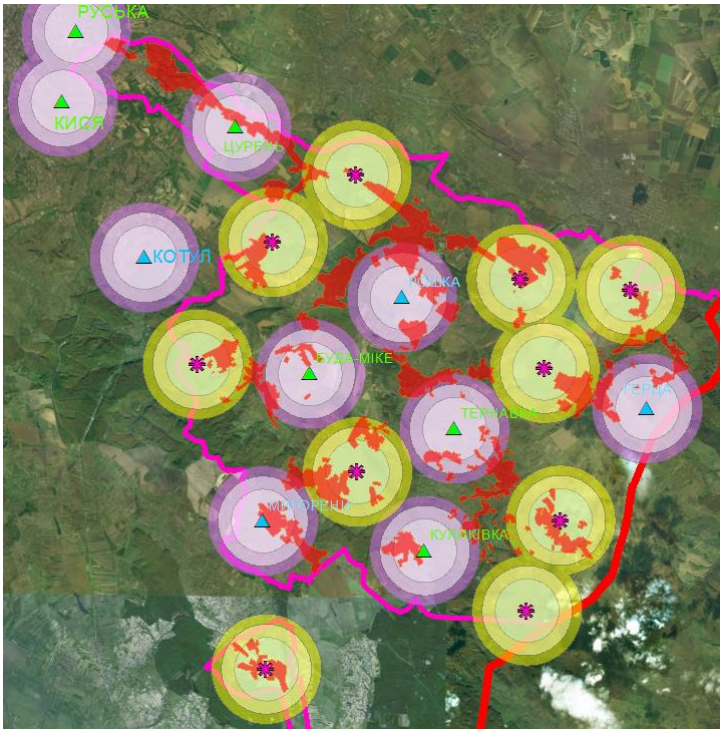


Figure 6: The possibility of drawing up topo plans on a scale of 1:2000, 1:1000 and 1:500 near Herts, Chernivtsi district, Chernivtsi region (image created using QGIS)

Figure 7: Location of points of polygonometry (image created using QGIS)

At present, as a result of the reconstruction of the road network and the development of

adjacent territories, a significant part (up to 70%) of these points is lost, which requires their restoration or densification. Given that this requires significant funds, it is advisable to create a dense filming (working) network localized to a specific place of search operations with the mandatory use of GPS receivers. In general, it was possible to obtain almost 600 polygonal objects for areas underpopulated areas for the entire Chernivtsi region. It was established that buffer coverage even of the largest radius of action does not exist for the entire part of the largest settlements in terms of area. In the case of smaller studied polygonal objects - settlements - the overlapping of the radius of the buffer is also not always monitored. The problematic point is strengthened when analyzing the possibility of creating topographic plans on a scale of 1:500 for the territory of the Chernivtsi region. That is, the area of areas of settlements that require geodetic support is increasing. The paper calculates the area of the areas of the territories of settlements that require additional geodetic support, as indicated above, on a scale of 1:25000-1:500 (Table 2). With the change in the scale series, the number of vectorized objects belonging to areas of non-compliance with geodetic support increases from 352 to 561, while the total number of vectorized objects in the territories of settlements of the studied object is about 600 (Fig. 8).

Table 2: Characteristics of the areas of settlements in the territory of the Chernivtsi region, regarding non-compliance with geodetic support.

№	*Requirements for placement of SGN points according to the scale*			*The size of the territories of non-compliance with geodetic support*		
	Scale	*Area*	*Buffer radius, km*	*Number of vectorized objects.*	*Area - km^2*	*% of the total area of settlements in the region*
1	1:10000-1:25000	30	3.1	352	1152.7	68.6
2	1:5000	20	2.52	450	1508.4	89.8
3	1:2000	15	2.19	497	1576.5	93.8
4	1:1000	10	1.78	536	1614.3	96.1
5	1:500	5	1.26	561	1632.4	97.2

When changing the above requirements (buffer area and radius), both the area and the percentage of non-compliance with geodetic support from the total area of settlements of Chernivtsi region increase. In particular, at the largest buffer scale of 3.1 km, the specified area and percentage are the lowest and amount to 1152.7 km^2 and 68.6%. Considering the possibility of creating plans at a scale of 1:500 for the territory of Chernivtsi region, the area of non-compliance with geodetic support as well as the percentage of the total area of settlements is the largest and is 1632.4 km^2 and 97.2%.

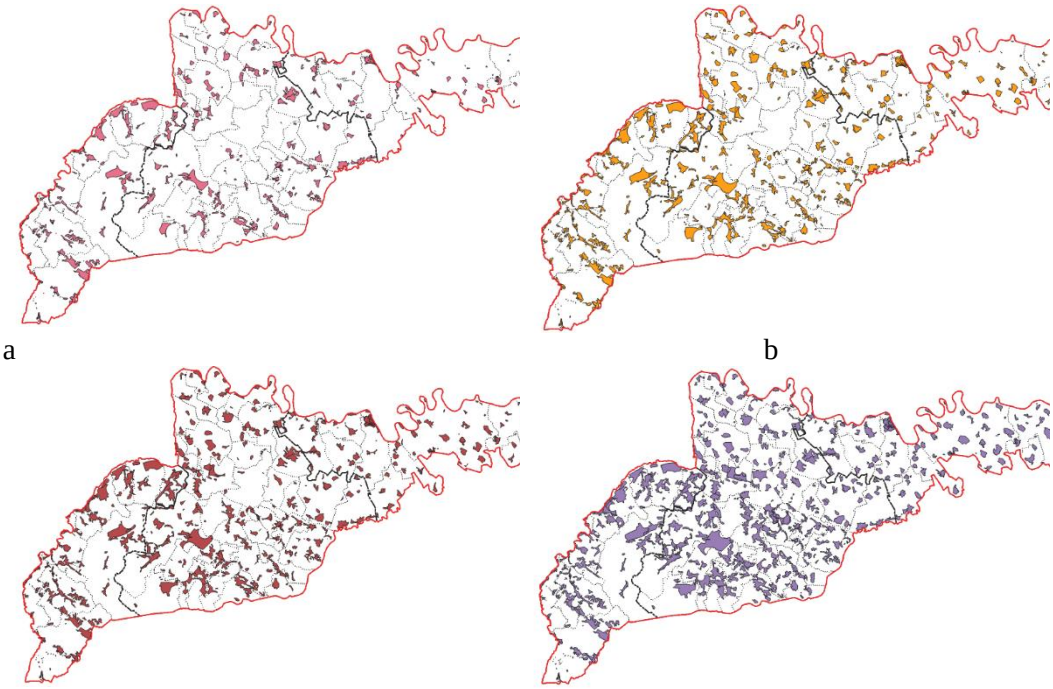


Figure 8: Areas of populated areas of the territory of Chernivtsi region, regarding non-compliance with geodetic support with a buffer radius of a) 3.1 km; b) 2.52 km; c) 2.19 km; and d) 1.78 km (image created using QGIS)

Discussion

For an objective assessment in general or the modern use of natural resources, it is important to map the territory with the exact positioning of individual geo-objects. Topographical and geodetic support of the research area showed the possibility of creating maps according to current requirements for a small scale. Unlike previous studies of geodetic support at the national (Karpinskyi and Hevel, 2022; Lepetyuk *et al.*, 2006; Sossa and Musienko, 2018; Trevogo, Ilkiv and Galyarnyk, 2022; Zayets, 2010), regional (Bilokrynytskyi, Darchuk and Melnyk, 2023; Darchuk *et al.*, 2021) levels, it was possible to use the QGIS functionality for the first time to determine and analyze the spatial characteristics of quantitative indicators of geodetic support inconsistency for the territory of Chernivtsi region. The following studies foresee the thickening of the state geodetic network. Projected points of different classes and values will allow you to draw up maps and plans on a large scale. The latter is quite important for the territories of settlements. Information about geodata, their exact location and attributes must be provided simultaneously for significant territories and regularly updated, while its objectivity must be ensured while maintaining the necessary accuracy of displaying the spatial position of objects. Currently, there are information databases in Ukraine, including on natural resources, in many different organizations and institutions. In recent years, due to the war in Ukraine, some portals and official state websites have closed access to geodata. Access and sharing of such information is essential for an accurate assessment. In the future, the formation of a geo-information base of topographic-geodetic data and other cartographic thematic information of various branches in the

raster and vector form of various scales is required. Among them, the formation of a geoinformation database of remote sensing of the earth with their appropriate processing in combination with traditional terrestrial methods is important. The war in Ukraine also negatively affects (there are significant restrictions even for educational institutions) the possibility of studying individual areas using unmanned aerial vehicles. The latter would allow for more accurate spatial characteristics of geo objects for creating base maps, including for the analysis of geodetic support (especially accurate visualization of the boundaries of settlements).

Conclusion

In the present study, an assessment of the spatial location of the DGM points for the territory of the Chernivtsi region by the modern administrative and territorial system was carried out. The number of geodetic points is 198 units of different classes. The largest number of SGN points is located within the Chernivtsi district - 109 units, which is 55% of the total number in the region, and in the Chernivtsi urban community - 41 units. It was established that there are areas of the region where there is a discrepancy in the average density of geodetic points with a total area of 2726.91 km^2 (33.7% of the total area). The largest area belongs to the Chernivtsi district and is 1281 km^2 (30% of the area of the administrative district). Among the basic units of the administrative-territorial system, the largest areas are in the Selyatynska village community - 238.85 km^2 (65% of the total area). Vectorization of settlements in the form of almost 600 polygonal objects was carried out. With the increase in scale, the possibilities of creating maps and plans for the territories of settlements of the Chernivtsi region, considering the existing points of SGN, are quite low. The territories of most settlements require additional design and creation of SGN points. The study helps to evaluate the permanent GIS approaches to the formation of geodetic data banks, to identify weak links of the most important geospatial basis, which is naturally lacking for the compilation of maps of the most important large-scale series. Further trends in the development of the geodetic industry make it possible to level these gaps through the development of permanent geodetic stations, with the subsequent involvement of GNSS receivers in static or RTK modes. Despite this, the analysis of modern geodetic support makes it possible to predict the volume of geodetic works when solving any economic problems that require an accurate cartographic basis, among which it is worth noting cadastral activity, construction work, utilization of natural resources, spatial planning, when drawing up project estimate documentation, etc. In addition, the theoretical and methodological provisions of the work can be used in similar studies for other similar objects in our and related areas.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	No	Yes	No	No
Collected the data	No	Yes	Yes	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes	No	No	No
Wrote the article/paper	Yes	Yes	Yes	Yes	Yes
Critical revision of the article/paper	Yes	No	No	Yes	Yes
Editing of the article/paper	No	Yes	Yes	No	No
Supervision	Yes	No	No	Yes	Yes
Project Administration	No	Yes	Yes	Yes	Yes
Funding Acquisition	No	No	No	No	No
Overall Contribution Proportion (%)	20	20	20	20	20

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